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# Geographic distribution of smallmouth bass, *Micropterus dolomieu*, in Nova Scotia: history of early introductions and factors affecting current range

# Distribution géographique de l'achigan à petite bouche, *Micropterus dolomieu*, en Nouvelle-Écosse : historique des premières introductions et facteurs déterminants de son aire de distribution présente

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## ABSTRACT

Since the first introduction of smallmouth bass (*Micropterus dolomieu)* into Nova Scotia in 1942, the number of occurrences in lakes and rivers increased to 188 by 2008 due to accidental and illegal transfers and dispersal within watersheds. Smallmouth bass are present in all but five counties but are more concentrated in Halifax, Lunenburg and Yarmouth counties. The majority of smallmouth bass in Nova Scotia occupy lakes and the prevalence in and utilization of riverine habitat is not well understood. Lake morphology appears to be a good predictor of the probability of establishment and shorter aquatic growing seasons in certain regions may function to prohibit, reduce or delay establishment. Smallmouth bass were confirmed in Lake Ainslie, Inverness County in 2003 and by 2007 had limited reproductive success but show evidence of young of the year winter survival. All new occurrences of smallmouth bass, as reported by anglers, are assigned a confidence ranking and subsequently followed up on by field staff. Waterbodies are only added to the distribution list once the presence is confirmed.

## RÉSUMÉ

Depuis la première introduction de l'achigan à petite bouche (*Micropterus dolomieu)* en Nouvelle-Écosse en 1942, les occurrences de l'espèce dans les lacs et rivières ont augmenté et atteint 188 localités en 2008. Cette augmentation parmi les bassins versants s'explique par des transferts accidentels et illégaux. On retrouve présentement l'achigan à petite bouche dans tous les comtés de la Nouvelle-Écosse, sauf cinq, et l'espèce est particulièrement abondante dans les comtés de Halifax, Lunenburg et Yarmouth. On retrouve l'espèce principalement dans les lacs mais sa distribution et son utilisation d'habitat riverain sont très peu connus. Les caractéristiques des lacs semblent être des facteurs prédictifs de la probabilité d'établissement de l'espèce. Une saison de croissance raccourcie dans certaines régions de la province pourrait ralentir sinon prévenir l'établissement de l'espèce. La présence de l'achigan à petite bouche a été confirmée dans le lac Ainslie, comté Inverness en 2003. Par 2007, on a eu des indications de succès de reproduction limité mais les jeunes de l'année semblent avoir un bon succès de vie durant l'hiver. Les rapports de nouvelles occurrences de l'achigan à petite bouche provenant des pêcheurs sportifs sont premièrement assignés une cote de fiabilité en attendant d'être confirmés. Les cours d'eau sont ajoutés à la liste de distribution géographique que lorsque la présence de l'espèce est confirmée par les agents de terrain.

## INTRODUCTION

The intentional or accidental movement of non-native smallmouth bass (*Micropterus dolomieu*) has contributed substantially to the current geographic distribution of this species in Nova Scotia. It is illegal to release live fish into the waters of the province without a permit because of the potential threat to local fish populations (ex. trophic alterations, competitive exclusion, predator-prey relationships, changes in littoral zone fish assemblages). However, since the original authorized introductions in Nova Scotia in the 1940s, the number of documented occurrences of smallmouth bass has increased to 188 water bodies by 2008 (Table 1, Fig. 1) and supports a significant recreational fishery. Smallmouth bass angling in Nova Scotia contributes an estimated $ 7 million to the economy annually. Smallmouth bass have become an important species within the recreational sport fishery and have been in the top five preferred species in Nova Scotia, by resident anglers, for the last 15 years (Nova Scotia Department of Fisheries and Aquaculture 2005). However, there continues to be a polarization of opinions about smallmouth bass in the province; within the angling community, and fisheries science and management.

Educational materials designed to inform about the potential negative consequences of illegal transfers have been widely utilized but unsuccessful in reducing the number of unauthorized introductions in recent years. Since the mid-1980s the number of documented occurrences of smallmouth bass has increased (Fig. 2). Ineffective legislation continues to be an impediment to reducing the threat even further. The main vectors of transfer in Nova Scotia, apart from the original government introductions, are illegal transfers, natural dispersal within watersheds and to a lesser extent, accidental releases; ex. live bait releases. New introductions documented during the development of this publication are not included. Data represents a complete data set up to and including May 2009 (i.e. Blacketts Lake, Cape Breton County).

The purpose of this report is to review the early introductions of smallmouth bass in Nova Scotia, in the context of range expansion since the 1940s and discuss the current status of this species. Nova Scotia has 6674 lakes of 1 hectare or greater in surface area (Alexander et al. 1986) and smallmouth bass currently occupy less than 3% of these. However, this represents approximately 9.5% of the total surface area (21,530 ha) of lake habitat in the province. There are several lake morphological characteristics, such as lake surface area and mean depth, that lead to an increased probability of smallmouth bass occupancy as well as regional differences in thermal regimes that seemingly limit, prohibit or delay establishment.

## HISTORICAL RANGE

The native range of smallmouth bass (*Micropterus dolomieu*) has been shown to be limited to areas of the Mississippi and Great Lakes basins in North America (MacCrimmon and Robbins 1975) during the late Pleistocene glaciation. During this period a wide range of fluvial conditions facilitated re-colonization of coldwater species and co-existence with warmwater fishes during glacial retreat (Radforth 1944). Post glacial water levels, topography and mean summer temperatures (Coleman 1922) likely facilitated localized movements but smallmouth bass were unable to exploit dispersal opportunities throughout New England and were therefore constrained by the Appalachian mountain range. In 1825 smallmouth bass were reported to have accessed the Hudson River valley when the Erie Canal was opened and soon dispersed throughout New England and the Middle Atlantic states (Bain 1993).

## INTRODUCTIONS INTO NOVA SCOTIA AND CURRENT DISTRIBUTION

In the Maritime provinces, smallmouth bass first occurred in New Brunswick during 1870 (Arndt 1996; MacCrimmon and Robbins 1975) and in Nova Scotia in Bunkers Lake, Yarmouth County in 1942 (Catt 1949). It was a sanctioned introduction by Government to develop new recreational fisheries where traditional fisheries for speckled (brook) trout were diminished due to over harvesting, habitat alterations, poor land use practices, eutrophication and acidification. Additionally, a general warming trend has limited the seasonal availability of cool water habitat for salmonid species in many areas of Nova Scotia (MacMillan et al. 2005). Early introductions in Nova Scotia (Table 2) from established populations in New Brunswick lakes were both successful and unsuccessful and occurred using varying numbers of individuals (n=16 to 108 individuals) but no records indicate that any introductions occurred using fish from their indigenous range (McNeill 1995). McNeill (1995) provides a detailed account of early introductions in Nova Scotia:

> "The first successful planting occurred in 1942 when 107 adults were taken from Wheatons Lake, New Brunswick, to Bunker Lake, Yarmouth County, Nova Scotia (Catt, 1949). During 1944-1953, 10 lakes in Nova Scotia were stocked with smallmouth bass, 6 of which developed sustaining populations (Catt, 1949; Gilhen, 1974). After 1953 government-sanctioned stocking of smallmouth bass ceased until 1967. During that interim, lake survey records and angler reports revealed that unauthorized introductions and natural dispersal within watersheds increased the number of lakes inhabited by smallmouth bass."

In 1954, Norwood Clearwater Lake in Digby County was illegally stocked with bass. By 1966 there were 23 known occurrences of smallmouth bass inclusive of the six original introductions that became established: Bunkers Lake (1942), Yarmouth County, Micmac Lake (1944), Halifax County, Lily Lake (1948), Hants County and Elliot Lake (1950), Annapolis County. However, the distribution in Yarmouth and Halifax counties was limited to lakes in the vicinity of the original introductions and remained isolated to Elliot Lake, Annapolis County and Lily Lake, Hants County. The next known occurrences were not documented until 1982 in Hants County with an additional 11 lake populations and not until 1992 in Annapolis County where there are currently seven other lake populations and one stream occurrence.

> "In 1967 and 1968, the Nova Scotia Department of Lands and Forests, with the approval of the Federal Department of Fisheries and Oceans (DFO) and the Nova Scotia Light and Power Co. Ltd., introduced smallmouth bass into Lumsden Pond, Black River Lake, Gaspereau Lake, and Methals Lake in Kings County (Bain, 1993). These and other lakes, by virtue of a hydroelectric power development, form what is known as the Gaspereau- Black River Complex and have developed into the premier smallmouth bass fishery in the province. " (McNeill 1995).

The Gaspereau – Black River Complex, Kings County provided recreational angling opportunities by 1982 (Sabean 1984) and continues to support one of the most important smallmouth bass fisheries in the province. Length of bass caught in tournaments has increased since 1995 and growth and relative weight is near the Nova Scotia average of 77 (LeBlanc and Halfyard 2008a) typical of stable populations in the province. Since 1970 there have been nine new occurrences of bass in Kings County, likely the result of migration within the hydroelectric development and illegal transfers. Murphy Lake, Kings County was stocked in 1984 with 124 adult bass from Black River Lake by the Nova Scotia Department of Natural Resources with permission from the Federal government. This was the last authorized smallmouth bass introduction in the province and continues to provide quality angling opportunities. In 1971,

Spectacle Lake, Digby County, was stocked by the Government of Canada and a successfully reproducing population was established in coexistence with chain pickerel (*Esox niger*) (McNeill 1995). There have been 18 subsequent occurrences of smallmouth bass in Digby County since 1971 several of which have developed into viable smallmouth bass fisheries. The majority of new populations, regardless of the vector of transfer, occur in Halifax and Lunenburg Counties (Fig. 3). These two counties combined represent approximately 44% of the known smallmouth bass occurrences in the province. Smallmouth bass exist in 14 of 18 counties in Nova Scotia. They first occurred in Colchester County in 1988 and Cumberland County in 1999. Other attempts were made in Blair Lake (1950) and Laytons Lake (1945-46) in Cumberland County but were unsuccessful. An earlier introduction of 300 fingerlings is believed to have occurred (Catt 1949) into Layton's Lake, Cumberland County from Lockharts Lake, New Brunswick in 1908 and thought to have not established due to a large resident perch population. This was the only time on record that bass at this stage were introduced. All other introductions were adult fish. No smallmouth bass were collected during field sampling of Laytons Lake (gill nets and angling) in 2003. The first confirmation of smallmouth bass in Queens County was 1989, in Shelburne County in 1997, and Pictou County in 2002. The first documented occurrence of smallmouth bass on Cape Breton Island occurred in Lake Ainslie, Inverness County in 1999 or 2000 and then in Blacketts Lake, Cape Breton County in 2009.

Although habitat modeling and predicting potential bass occurrences using suitability indices can be useful (Vander Zanden et al. 2004; Bozek et al. 2002) and certainly preventing illegal transfers and establishment are important policy goals, the occurrence of new populations from illegal transfers is difficult to monitor and prevent. Additionally, dispersal within watersheds is equally difficult to track given the complexities of fish movement and biological issues surrounding invasion. The intricacy of forecasting accidental or even intentional transfers results in reactionary monitoring. Since 1990 the Nova Scotia Department of Fisheries and Aquaculture has adopted a ranking system to record new reports of smallmouth bass, chain pickerel (*Esox niger*) and common carp (*Cyprinus carpio*). A single report from a non-angler source (ex. land owner, researcher, anonymous) is assigned a confidence level of 0, a single report from an angler is assigned a confidence level of 1, and multiple reports from anglers for the same location are assigned a confidence level of 2 (Table 3). It is important to note that no greater or lesser value is assigned to an angler report based on how knowledgeable or experienced the angler is because observations of an angler may be equally as valid as survey data (McNeill 1995). All reports on potential occurrences of smallmouth bass are subsequently followed up on by fisheries staff in an effort to confirm distributional data. There are currently 52 reported locations that have not been followed up completely to date. Occasionally new populations of bass are found during regular lake survey gill and trap netting as was the case with the 2009 occurrence of smallmouth bass in Blacketts Lake, Cape Breton County.

## IMPEDIMENTS TO ESTABLISHMENT

In Nova Scotia smallmouth bass primarily inhabit lakes but are found to occur in various other waterbodies throughout their range (Coble 1975) from cool, clear lakes with rocky shoals and gravel or cobble substrates to slow moving streams with deep pools that have cover features such as logs, boulders and overhangs. Using the Fisheries Inventory of Nova Scotia (FINS) database with smallmouth bass distributional data, two sample t-tests assuming equal variances suggests the presence of smallmouth bass is significantly correlated with lake surface area, mean depth, maximum depth and the shoreline development index. Secchi disk was not a good predictor of smallmouth bass presence (Table 4). It may be possible to predict the potential occurrence of smallmouth bass within watersheds based on some of these lake

morphological features. Conversely, this data suggests that the probability of bass establishing populations in small, shallow lakes is lower than large, deeper lakes.

The length of an agricultural growing season may be a useful predictor of the presence of smallmouth bass whereby a minimum of 95-100 frost free days (FFD) might be required for establishment (Hubert, 1988). Additionally, the length of the aquatic growing season is a major factor affecting growth rate and age at maturity (Coulant 1975). These requirements were thought to potentially restrict establishment in areas of Cape Breton (Hebda et al. 1990) and some regions of mainland Nova Scotia. Although coastal Nova Scotia experiences relatively mild winters, there are regions where the mean daily temperature only decreases to 0 °C or below for short periods of time, effectively extending the growing season in both spring and fall or the total number of FFD. Conversely, there are regions of the province that have a substantial number of days that drop to at least 0 °C and have a higher probability of frost. Coastal areas tend to have low probability of frost and interior regions within Inverness County (Lake Ainslie), Cumberland, Colchester, Pictou, Guysborough and Halifax counties have a 90% chance of having frost after May 28 (Figure 4) which could restrict colonization, have negative effects on spawning success and result in poor year class strength and subsequent recruitment. Relating the current smallmouth bass distribution for the province to areas with a shorter growing season (fewer FFDs) illustrates that there are no known bass populations in what will be referred to as the "temperature exclusion zones". The exact boundaries of what would represent the temperature exclusion zones have not been determined, however for the purposes of this discussion would include the interior of Inverness County from Cheticamp south to Port Hastings, northeastern Halifax County where it intersects Guysborough, Pictou and Colchester counties, the Cobequid mountain range and extending west to the New Brunswick border. Layton's Lake, Cumberland County, in which smallmouth bass were unsuccessfully introduced on three separate occasions, is located within this zone. Lake Ainslie is within this zone, currently has an established population of smallmouth bass and represents an interesting exception.

**Lake Ainslie Population**

Inland Fisheries confirmed the presence of smallmouth bass in Lake Ainslie, Inverness County on September 23, 2003 following an angler report. Lake Ainslie is the largest natural freshwater lake in Nova Scotia and empties into the Southwest Margaree River. Documented introductions of smallmouth bass throughout northern Nova Scotia and in rivers draining into the Gulf Region have been limited. This Lake Ainslie occurrence represented the first documented introduction of smallmouth bass on Cape Breton Island. Since that time smallmouth bass and chain pickerel have been found in the Sydney River watershed.

Many aspects of the biology of smallmouth bass are influenced by natural variations in water temperature, including the timing of reproduction and reproductive success (Armour 1993). It has also been shown that instability in water temperature has the potential to affect spawning adults and young differently, ultimately affecting aspects of parental care, timing of spawning, offspring development and brood survival (Cooke et al. 2003). Nest abandonment can occur when water temperatures dip below 15 °C (Latta 1963) and several studies have reported that thermal variations as small as 2 °C may result in nest abandonment (Rawson,1945 ; Henderson and Foster 1957). It was thought that the potential for smallmouth bass establishment in Lake Ainslie could be limited by the high likelihood of frost events during the normal spawning period and the area's propensity for shorter growing seasons as discussed previously. The last frost in spring at the Margaree Forks, Nova Scotia weather station (near Lake Ainslie) is generally not until June 16 or later and has occurred as late as July 10. The first frost in the fall is generally

September 16 or earlier and has occurred as early as August 19 (Environment Canada 1980). A 20 year data set for this station reveals that Lake Ainslie averages 91 FFD (range 65-124). Given that nest building would be delayed 9 out of 10 years and feeding declines drastically below 6 °C further restricting seasonal growth potential, smallmouth bass predictably could have difficulty becoming established in Lake Ainslie and young of the year could experience high first winter mortality. Overwinter mortality of young of the year has been shown to be influenced by size, energy reserves and temperature (Oliver and Holeton 1979). In New Brunswick populations post-winter collections of age-0 bass indicated high winter mortality of fish less than 5.0 cm (Curry et al. 2005). Longer winters, relative to other areas of Nova Scotia would therefore require maximum age-0 size to survive the starvation period. Age-0 bass collections to assess the size of young of the year bass heading into the first winter should be conducted to determine if year class strength could be comprised by winter survival.

Following the first angler report from Lake Ainslie in 2003 annual catch assessments were conducted to monitor catch per angler hour or catch per unit effort (CPUE). Angler creel surveys were limited and highly variable and white perch were often reported as bass so only catch by fisheries staff is presented here. From 2003 -2008 bass catch increased from 0.3 bass/hr to 1.63 bass/hr (Table 5; Figure 5). Speckled trout catch decreased from 1.5 trout/hr to 0.11 trout/hr during the same time period. However, it is too preliminary to conclude that declining speckled trout catch rates is attributed to increases in smallmouth bass abundance. Natural variation in wild trout abundance, influenced by fall fingerling enhancement from the Margaree Fish Hatchey and trout harvest from the recreational fishery could all influence trout CPUE during this survey. Seasonal variation in CPUE shows a decline in trout catch from May 26 to July 16 from 1.6 trout/hr to 0 trout/hr (range 0-1.71 trout/hr) which for this waterbody has been typical as the lake warms and trout seek out cooler water in tributaries (Figure 6). Inversely, CPUE for bass increased during the same time period from 0 bass/hr to 1.5 bass/hr (range 0-1.73 bass/hr). This is typical of bass lakes in other areas as water temperature increases and bass shift from spawning to feeding behaviour.

Until 2008, sample sizes were too small to assess length at age data. Length at age data for 143 bass caught in 2008 is presented in Figure 7. Smallmouth bass as old as 9 years implies that they could have been present in Lake Ainslie as early as 2000 with low enough abundance to be undetected by the current level of angling. Contrary to expectations based on a limited growing season, bass in Lake Ainslie reach 22.3 cm by age 3, 34.0 cm by age 6 and 40.3 cm by age 9. This growth is similar to bass in Ogden, Parr and Petes lakes, Yarmouth County, at their most southern distribution in Nova Scotia (LeBlanc and Halfyard 2008b). High prey item abundance during key feeding periods and developmental stages may compensate for any thermal restrictions discussed earlier. Little data is available for smallmouth bass younger than age 2, however in many populations in Nova Scotia bass of ages 1, 2 and 3 exhibit growth rates similar to the North American average (Dunlop and Shuter 2004). This may also be important when assessing winter survival.

Littoral zone water temperatures in Lake Ainslie do not tend to reach 15 °C for a sustained period until mid-June (Figure 8) whereas in established smallmouth bass populations in mainland lakes nest building is typically well under way by May 20-24 (LeBlanc and Heighton 2008, unpublished). Shoreline surveys of approximately 90% of available spawning habitat from 2003-2005 did not confirm reproductive success or any spawning activity at all. In 2006 nest building was documented on June 12 and June 13 in five locations. None of these nests received eggs nor was male guarding behaviour observed during what would be considered the spawning period. Subsequent captures of age 2+ bass caught in 2008, however, strongly suggest that successful spawning and first winter survival occurred and that life cycle closure

occurred in 2006 but was missed by researchers. Year-class strength in northern populations of smallmouth bass is strongly influenced by winter starvation of young-of-the-year (Shuter et al., 1989). During the 2007 field season 2 smallmouth bass nests were documented yet no eggs were deposited during that spawning period either. In 2008 at least 6 nests were documented by July 16 of which 3 produced swim-up fry and male guarding behaviour was observed. Nests in which the guarding male is able to protect the brood up to the swim-up fry stage are considered successful (LeBlanc and Heighton, 2008, unpublished). It can be assumed that there were other successful nests in 2008 as swim-up fry were observed in 3 other locations, however the nests and guarding male bass were not observed. Additional nesting and population density index surveys are planned for subsequent years.

Preliminary assessment of smallmouth bass stomach samples from Lake Ainslie suggest a diet dominated by insects however additional sampling is required to assess the degree to which bass feed on salmonids (particularly speckled trout), juvenile gaspereau, white perch and littoral zone fishes.

## USE OF RIVERINE HABITAT IN NOVA SCOTIA

Consistent with populations throughout the northern part of their range, and unlike southern populations where they are primarily a riverine species, smallmouth bass in Nova Scotia are found primarily in lakes. In rivers and streams elsewhere, bass can often be found near undercuts and deeper pools (Rankin 1986) and just outside of the river current's direct flow. They also utilize the downstream side of fallen logs, trees, and stumps and prefer adjacent weed beds.

Riverine populations in Nova Scotia are not well documented, however, there are smallmouth bass throughout the lower Mersey River (series of impoundments), Carleton, Shubenacadie, Sackville and LaHave river drainages. Smallmouth bass in the LaHave River watershed utilize large pools and backwaters below lake populations but it is unclear what biological function the river provides (ex. feeding, over-wintering, spawning).

## DISCUSSION

The limited North American distribution of smallmouth bass, post Pleistocene glaciation, appears much different now following decades of introductions within North America and subsequent global transfers to Africa, Asia, Europe, Central America and South America. Nova Scotia has had established populations since 1942 and has smallmouth bass populations and occurrences in most regions of the province. Although the documented number of bass populations is 188, the probability that additional populations exist is high given the extent to which angler reports can be investigated. It is clear that the introduction of a non-native species, particularly a top level predator has the potential for negative interactions with fauna in the recipient water body. Gozlan (2008) suggests that the risk of ecological impact after an introduction of a freshwater fish species is less than 10% for the majority of introduced fish. For Centrarchids, the family to which smallmouth bass belong, the likelihood of ecological impact is thought to range from 0 to 27% (Kolar and Lodge 2002). For consideration is that not all introductions become established as is evident in the history of smallmouth bass in Nova Scotia. Seven out of seventeen (41%) of historically attempted and authorized introductions established populations. This is substantially higher than the suggested establishment rate of

the "tens rule" whereby only 10% of introductions become established and only 10% of those have impacts on organisms in the donor environment (Williamson 1996). Following this rule there could have been as many as 1,880 attempts at establishment (cumulative of illegal transfers, authorized introductions and dispersal events) in waterbodies in Nova Scotia, however this seems unlikely and not to be the case. Application of the "tens rule" to the current list in Table 3 suggests an additional five locations would have established populations. However, the historical successes of authorized introductions in Nova Scotia implies that there could be an additional 22 lakes. The predicted number of established smallmouth bass populations in Nova Scotia could range from 193 to 211. The utility of this tool for Nova Scotia could be tested when investigating new reports of smallmouth bass.

Contrary to the temperature exclusion theory proposed earlier, smallmouth bass have established in Lake Ainslie and exhibit similar population characteristics to young populations in other areas of Nova Scotia and demonstrate growth rates similar to the North American average for fish less than age 4 (Dunlop and Shuter 2004). It is expected that given the substantial prey availability in Lake Ainslie bass growth will continue to be high at least at current abundance levels. This is substantiated by high relative weight measurements near 100 and far greater than the Nova Scotia mean value of 77 (LeBlanc and Halfyard 2008a). Higher relative weights seems to be typical of new smallmouth bass populations in Nova Scotia but is an area that requires additional attention. Big Mushamush Lake, Lunenburg County, thought to have had bass introduced in 1994 continues to exhibit high growth rates and arguably maintains a stable predator-prey balance. However, Ten Mile Lake, Queens County, which exhibited fast growth during the early stages of population development may now be showing signs of an imbalance between predator and prey abundances.

Climate change and the subsequent propensity for incremental warming could further reduce the availability of summer thermal refugia habitat in Nova Scotia for cold water species such as speckled trout and increase available habitat for species more tolerant of temperature fluctuations such as smallmouth bass, chain pickerel and yellow perch. For example, a 2°C increase in summer mean water temperature could result in a 50% loss of cool water stream habitats and a dramatic increase in warm water habitats (MacMillan et al. 2005; Sharma et al. 2007). This could facilitate establishment where prior to temperature increases conditions were unsuitable for smallmouth bass establishment.

Lake morphological characteristics such as surface area and mean depth can be useful in predicting the potential for smallmouth bass to establish in a particular waterbody. However, no known threshold values for lake morphological features which exclude smallmouth bass were evident, rather an inference to more suitable lacustrine habitat features. Additionally, a significant vector for new occurrences is illegal transfers. Consideration must be given to angler activity and preferences and the proximity of newly documented populations to established ones. Other lake parameters that should be considered are pH, the area of the lake that has depths less than 6 m, chlorophyll a, and colour. Experimental results considering interactions of low pH and starvation on body weight of young of the year smallmouth bass suggest that at pH < 5.0 changes in tissue composition related to starvation were accentuated (Cunningham and Shuter 1986). Several other studies indicate that smallmouth bass have a low tolerance to acidic conditions (Rahel and Magnuson 1983; Beamish 1976). In Nova Scotia, poor condition during the winter starvation period could reduce the tolerance bass may have to low pH. Several regions of Nova Scotia experience seasonal acidic conditions during spring run-off periods which could result in high young of the year mortality as Snucins and Shuter (1991) reported for many Ontario lakes. However smallmouth bass populations persist in some acidic areas in Nova Scotia and exhibit average or above average growth (MacMillan and Robinson

1999). Further research in this area is important to predicting establishment in acid stressed regions.

River and stream usage of smallmouth bass is not clearly understood but have provided mechanisms for dispersal within watersheds. Biological aspects of riverine habitat utilization related to feeding behaviour, over wintering and spawning functions need to be addressed in order to provide evidence based commentary as to any potential impacts on riverine species assemblages. Investigating some of these questions may provide pertinent data for assessing potential impacts of smallmouth bass in the Margaree and Miramichi watersheds.

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*Table 1. Known distribution of smallmouth bass in Nova Scotia in 2009. (A) denotes authorized introductions which established populations.*

| Water Body | County | First Known Occurrence | Latitude (Deg Min) | Longitude (Deg Min) |
|---|---|---|---|---|
| Elliot Lake[(A)] | Annapolis | 1950 | 4456 | 6511 |
| Paradise Lake | Annapolis | 1989 | 4446 | 6510 |
| Youngs Lake | Annapolis | 1992 | 4449 | 6526 |
| Grand Lake Flowage | Annapolis | 1993 | 4439 | 6528 |
| Nictaux River | Annapolis | 1997 | 4456 | 6504 |
| Waterloo Lake | Annapolis | 2000 | 4444 | 6459 |
| Molly Upsim Lake | Annapolis | 2000 | 4440 | 6503 |
| McGill Lake | Annapolis | 2000 | 4442 | 6500 |
| Lambs Lake Outflow | Annapolis | 2006 | 4440 | 6528 |
| Blacketts Lake | Cape Breton | 2009 | 4607 | 6030 |
| Shortts Lake | Colchester | 1988 | 4512 | 6319 |
| Round Lake | Colchester | 1999 | 4539 | 6327 |
| Big Lake | Cumberland | 1998 | 4555 | 6344 |
| Mattatall Lake | Cumberland | 2001 | 4542 | 6328 |
| Angevine Lake (Dewar Lake) | Cumberland | 2001 | 4544 | 6331 |
| Randalls Lake | Cumberland | 2002 | 4540 | 6404 |
| Clearwater (Norwood) Lake | Digby | 1954 | 4405 | 6603 |
| Spectacle Lake[(A)] | Digby | 1971 | 4417 | 6607 |
| Lac D'en Bas | Digby | 1973 | 4416 | 6604 |
| Cornings Lake | Digby | 1975 | 4403 | 6605 |
| Lower Cornings Lake | Digby | 1976 | 4403 | 6605 |
| Indian Pond | Digby | 1976 | 4403 | 6605 |
| Churchills Lake | Digby | 1981 | 4404 | 6604 |
| Doucette Lake | Digby | 1988 | 4404 | 6608 |
| Wentworth Lake | Digby | 1992 | 4411 | 6556 |
| Privilege Lake | Digby | 1992 | 4411 | 6555 |
| Lac a Victor | Digby | 1994 | 4419 | 6602 |
| Salmon River Lake | Digby | 1995 | 4411 | 6604 |
| Oakleaf Lake | Digby | 1995 | 4415 | 6602 |
| Cranberry Lake | Digby | 1996 | 4409 | 6606 |
| Weaver Lake | Digby | 1998 | 4422 | 6559 |
| Johnson Lake | Digby | 1998 | 4421 | 6559 |
| Grifiths Lake | Digby | 1998 | 4421 | 6559 |
| Midway Lake | Digby | 1999 | 4432 | 6603 |
| Spider Lake | Digby | 2002 | 4413 | 6557 |
| Micmac Lake[(A)] | Halifax | 1944 | 4441 | 6333 |
| Banook Lake | Halifax | 1946 | 4440 | 6333 |
| Charles Lake | Halifax | 1954 | 4443 | 6333 |
| William Lake | Halifax | 1959 | 4446 | 6335 |
| Thomas Lake | Halifax | 1960 | 4448 | 6337 |
| Shubenacadie Grand Lake | Halifax | 1961 | 4455 | 6336 |
| Fletcher Lake | Halifax | 1961 | 4450 | 6336 |
| Fish Lake | Halifax | 1961 | 4455 | 6335 |

*Table 1 (continued).*

| Water Body | County | First Known Occurrence | Latitude (Deg Min) | Longitude (Deg Min) |
|---|---|---|---|---|
| Powder Mill Lake | Halifax | 1965 | 4446 | 6337 |
| Penhorn Lake | Halifax | 1965 | 4440 | 6333 |
| Oathill Lake | Halifax | 1965 | 4440 | 6333 |
| Maynard Lake | Halifax | 1965 | 4440 | 6333 |
| Rocky Lake | Halifax | 1966 | 4500 | 6318 |
| Three Mile Lake | Halifax | 1970 | 4447 | 6338 |
| Third Lake | Halifax | 1970 | 4447 | 6338 |
| Kinsac Lake | Halifax | 1971 | 4450 | 6339 |
| Second Lake | Halifax | 1975 | 4446 | 6339 |
| Morris Lake | Halifax | 1975 | 4439 | 6330 |
| First Lake (Lower Sackville) | Halifax | 1975 | 4450 | 6239 |
| First Lake (Spry Harbour) | Halifax | 1978 | 4446 | 6339 |
| Loon Lake | Halifax | 1984 | 4442 | 6330 |
| Duck Pond | Halifax | 1984 | 4448 | 6341 |
| Albro Lake | Halifax | 1984 | 4441 | 6334 |
| Porters Lake | Halifax | 1988 | 4445 | 6318 |
| Hatchet Lake | Halifax | 1988 | 4434 | 6343 |
| Sackville River | Halifax | 1990 | 4450 | 6347 |
| McCabe Lake | Halifax | 1990 | 4447 | 6345 |
| Beaverback River | Halifax | 1994 | 4451 | 6340 |
| Tucker Lake | Halifax | 1995 | 4450 | 6341 |
| Russell Lake | Halifax | 1996 | 4439 | 6331 |
| Miller Lake | Halifax | 1996 | 4449 | 6336 |
| Beaverbank Lake | Halifax | 1996 | 4451 | 6340 |
| Sandy Lake (Lucasville) | Halifax | 2000 | 4446 | 6342 |
| Webber Lake | Halifax | 2002 | 4447 | 6344 |
| Kearney Lake | Halifax | 2002 | 4442 | 6342 |
| Egmont Lake | Halifax | 2002 | 4500 | 6318 |
| North River | Halifax | 2006 | 4451 | 6354 |
| Big Indian Reservoir | Halifax | 2006 | 4447 | 6355 |
| Lily Lake[A] | Hants | 1948 | 4505 | 6405 |
| Maitland Mill Pond | Hants | 1982 | 4518 | 6330 |
| Panuke Lake | Hants | 1983 | 4450 | 6406 |
| Pigott Lake | Hants | 1994 | 4456 | 6353 |
| Zwicker Lake | Hants | 1996 | 4449 | 6414 |
| Mockingigh | Hants | 1996 | 4451 | 6415 |
| Cogmagun Pond | Hants | 1996 | 4509 | 6358 |
| Uniacke Lake | Hants | 2001 | 4453 | 6354 |
| Murphy Lake | Hants | 2002 | 4451 | 6413 |
| Falls Lake | Hants | 2002 | 4451 | 6415 |
| Cockscomb Lake | Hants | 2002 | 4456 | 6351 |
| Big St. Margarets Bay Lake | Hants | 2002 | 4447 | 6405 |

*Table 1 (continued).*

| Water Body | County | First Known Occurrence | Latitude (Deg Min) | Longitude (Deg Min) |
|---|---|---|---|---|
| Lake Ainslie | Inverness | 2000 | 4603 | 6107 |
| Methals Lake[(A)] | Kings | 1967 | 4458 | 6426 |
| Lumsden Pond[(A)] | Kings | 1967 | 4501 | 6423 |
| Little River Lake[(A)] | Kings | 1967 | 4459 | 6428 |
| Gaspereau Lake[(A)] | Kings | 1967 | 4448 | 6433 |
| Four Mile Lake[(A)] | Kings | 1967 | 4456 | 6437 |
| Dean Chapter Lake[(A)] | Kings | 1967 | 4453 | 6427 |
| Black River Lake[(A)] | Kings | 1967 | 4458 | 6424 |
| Trout River Pond | Kings | 1970 | 4456 | 6431 |
| Moosehorn Lake | Kings | 1970 | 4459 | 6427 |
| Lake George | Kings | 1972 | 4456 | 6442 |
| Loon Lake | Kings | 1975 | 4454 | 6440 |
| Aylesford Lake | Kings | 1975 | 4457 | 6440 |
| Halfmoon Lake | Kings | 1978 | 4458 | 6442 |
| Murphy Lake[(A)] | Kings | 1984 | 4455 | 6432 |
| South Twin Lake | Kings | 1994 | 4451 | 6443 |
| North Twin Lake | Kings | 1994 | 4452 | 6443 |
| Midconner Lake | Kings | 2002 | 4451 | 6444 |
| Lake Paul | Kings | 2002 | 4452 | 6441 |
| Steverman Lake | Lunenburg | 1952 | 4429 | 6436 |
| Cantelope (Lilydale) Lake[(A)] | Lunenburg | 1952 | 4424 | 6421 |
| Pernette Lake | Lunenburg | 1986 | 4419 | 6428 |
| Blysteiners Lake | Lunenburg | 1986 | 4425 | 6429 |
| Becks Lake | Lunenburg | 1986 | 4421 | 6425 |
| Wallace Lake | Lunenburg | 1994 | 4422 | 6422 |
| Rhodenizer Lake | Lunenburg | 1994 | 4441 | 6425 |
| Big Mushamush Lake | Lunenburg | 1994 | 4430 | 6433 |
| Shingle Lake | Lunenburg | 1995 | 4423 | 6420 |
| Hunts Lake | Lunenburg | 1995 | 4447 | 6431 |
| Sucker Lake | Lunenburg | 1996 | 4428 | 6425 |
| Crouse Lake | Lunenburg | 1996 | 4422 | 6424 |
| Sherbrooke Lake | Lunenburg | 1997 | 4425 | 6448 |
| Moose Lake | Lunenburg | 1997 | 4417 | 6434 |
| LaHave River | Lunenburg | 1997 | 4416 | 6420 |
| Fancy Lake | Lunenburg | 1997 | 4428 | 6451 |
| Branch Lake | Lunenburg | 1997 | 4415 | 6433 |
| Wentzells Lake | Lunenburg | 1998 | 4431 | 6455 |
| Indian Lake | Lunenburg | 1998 | 4434 | 6438 |
| Round Lake | Lunenburg | 1999 | 4428 | 6441 |
| Randall Lake | Lunenburg | 1999 | 4423 | 6429 |
| Peter Lake | Lunenburg | 1999 | 4435 | 6439 |
| New Canada Lake | Lunenburg | 1999 | 4429 | 6441 |
| Little Mushalush Lake | Lunenburg | 1999 | 4431 | 6428 |

*Table 1 (continued).*

| Water Body | County | First Known Occurrence | Latitude (Deg Min) | Longitude (Deg Min) |
|---|---|---|---|---|
| Langille Lake | Lunenburg | 1999 | 4427 | 6427 |
| Pleasant River | Lunenburg | 2000 | 4427 | 6431 |
| Minamkeak Lake | Lunenburg | 2000 | 4417 | 6436 |
| Milipsigate Lake | Lunenburg | 2000 | 4420 | 6436 |
| Hebb Lake | Lunenburg | 2000 | 4421 | 6434 |
| Dares Lake | Lunenburg | 2000 | 4424 | 6422 |
| Andrew Lake | Lunenburg | 2000 | 4421 | 6439 |
| William Lake | Lunenburg | 2002 | 4436 | 6439 |
| Wagner Lake | Lunenburg | 2002 | 4416 | 6432 |
| Sefferns Lake | Lunenburg | 2002 | 4440 | 6436 |
| Lewie Lake | Lunenburg | 2002 | 4421 | 6440 |
| Church Lake | Lunenburg | 2002 | 4433 | 6436 |
| Big Otter Lake | Lunenburg | 2002 | 4447 | 6417 |
| Middle River Reservoir | Pictou | 2002 | 4539 | 6244 |
| Lansdowne Lake | Pictou | 2003 | 4526 | 6249 |
| Ten Mile Lake | Queens | 1989 | 4410 | 6451 |
| Little Ten Mile Lake | Queens | 1989 | 4409 | 6451 |
| Eight Mile Lake | Queens | 1989 | 4410 | 6448 |
| Mersey River | Queens | 1995 | 4402 | 6443 |
| Scott Lake | Queens | 1999 | 4422 | 6505 |
| Herring Cove Lake | Queens | 1999 | 4408 | 6443 |
| PonHook Lake | Queens | 2001 | 4419 | 6453 |
| Molega Lake | Queens | 2001 | 4422 | 6451 |
| Annis Lake | Queens | 2001 | 4420 | 6450 |
| West Horseshoe Lake | Shelburne | 1997 | 4402 | 6529 |
| Deception Lake | Shelburne | 1999 | 4354 | 6523 |
| George Lake | Shelburne | 2000 | 4348 | 6518 |
| Clamshell Lake | Shelburne | 2002 | 4402 | 6529 |
| Churchover Lake | Shelburne | 2002 | 4342 | 6523 |
| Bunkers Lake[A] | Yarmouth | 1942 | 4355 | 6605 |
| Second (Middle) Lake | Yarmouth | 1947 | 4352 | 6606 |
| Milo Lake | Yarmouth | 1947 | 4352 | 6606 |
| Doctors Lake | Yarmouth | 1947 | 4353 | 6606 |
| Brenton Lake | Yarmouth | 1952 | 4358 | 6604 |
| Two Island Lake | Yarmouth | 1976 | 4402 | 6604 |
| Cedar Lake | Yarmouth | 1978 | 4401 | 6607 |
| Killams Lake | Yarmouth | 1981 | 4400 | 6605 |
| Spectacle Lake | Yarmouth | 1989 | 4402 | 6606 |
| Petes Lake | Yarmouth | 1989 | 4404 | 6552 |
| Parr Lake | Yarmouth | 1989 | 4405 | 6554 |
| Odgen Lake | Yarmouth | 1989 | 4403 | 6554 |
| Peters Brook | Yarmouth | 1990 | 4359 | 6549 |
| Upper Crawleys Lake | Yarmouth | 1994 | 4403 | 6553 |

*Table 1 (continued).*

| Water Body | County | First Known Occurrence | Latitude (Deg Min) | Longitude (Deg Min) |
|---|---|---|---|---|
| Mink Lake | Yarmouth | 1994 | 4401 | 6554 |
| Lower Crawleys Lake | Yarmouth | 1994 | 4402 | 6554 |
| Harris Lake | Yarmouth | 1994 | 4354 | 6600 |
| Fanning Lake | Yarmouth | 1994 | 4401 | 6555 |
| Carleton River | Yarmouth | 1994 | 4356 | 6556 |
| Carleton Back Lake | Yarmouth | 1994 | 4401 | 6556 |
| Raynards Lake | Yarmouth | 1995 | 4358 | 6555 |
| Lake Vaughan | Yarmouth | 1998 | 4355 | 6558 |
| Kempt Back Lake | Yarmouth | 1998 | 4404 | 6551 |
| Hoopers Lake | Yarmouth | 2000 | 4357 | 6559 |
| Agard Lake | Yarmouth | 2000 | 4355 | 6600 |

*Table 2. Early known introductions of smallmouth bass in Nova Scotia (Bain 1993; Catt 1949; McNeill 1995). YOY refers to Young of the Year. All other introductions were adults.*

| Year | Waterbody | County | Number | Source | Agency | Status | Principle Bass Fishery |
|---|---|---|---|---|---|---|---|
| 1951 | Elliot Lake | Annapolis | 34 | Darlings Lake & Hammond River, NB | DFO | Present | No |
| 1950 | Blair Lake | Cumberland | 60 | Lake Utopia & Wheatons Lake, NB | DFO | Not present | |
| 1908 | Laytons Lake | Cumberland | 108 (YOY) | Lockharts Lake, NB | DFO | Not present | |
| 1945 | (second introduction) | | 53 | Lake Utopia, NB | DFO | | |
| 1946 | (third introduction) | | 37 | Lake Utopia, NB | DFO | | |
| 1971 | Spectacle | Digby | Unknown | Unknown | NSDNR | Present | Yes |
| 1952 | Fishermans Harbour Lake | Guysborough | 16 | Lake Utopia & Spectacle Lake, NB | DFO | Not present | |
| 1944 | Micmac Lake | Halifax | 61 | Lake Utopia, NB | DFO | Present | Yes |
| 1946 | (second introduction) | | 37 | Lake Utopia, NB | DFO | | |
| 1948 | Lily Lake | Hants | 44 | Lake Utopia, NB | DFO | Present | No |
| 1967 | Black River System (Includes: Black River Lake, Dean Chapter, Four Mile, Gaspereau, Little River, Methals and Lumsden lakes) | Kings | 748 | Micmac, Lily & Elliot lakes, NS | DFO / NSDNR | Present | Yes |
| 1984 | Murphy Lake | Kings | 124 | Black River Lake, NS | NSDNR | Present | Yes |
| 1953 | Awalt Lake | Lunenburg | Unknown | Spruce Lake, NB | DFO | Not present | |
| 1952 | Cantelope Lake | Lunenburg | 17 | Lake Utopia & Spectacle Lake, NB | DFO | Not present | |
| 1953 | (second introduction) | | Unknown | Lake Utopia & Spectacle Lake, NB | DFO | | |
| 1947 | Victoria Lake | Queens | 39 | Wheatons Lake[1], NB | DFO | Unknown | |
| 1942 | Bunkers Lake | Yarmouth | 107 | Wheatons Lake[1], NB | DFO | Present | No |

[1] Wheatons Lake, NB is also known as Bocabec Lake.

*Table 3. Potential occurrences of smallmouth bass in Nova Scotia that have not been investigated and confidence in angler reports. Confidence: Non-angler report (0), single angler report (1) and multiple anglers reports (2).*

| Water Body | County | Year | Topo Map | Latitude (Deg Min) | Longitude (Deg Min) | Confidence | Source |
|---|---|---|---|---|---|---|---|
| Scragg Lake | Annapolis | 2000 | 21A/15 | 4447 | 6459 | 1 | Angler logbook (caught 4) |
| Shannon Lake | Annapolis | 2000 | 21A/11 | 4445 | 6500 | 1 | Angler |
| Upper Mersey River | Annapolis | 2001 | 21A/06 | 4427 | 6511 | 1 | Researcher at MTRI |
| Shannon River | Annapolis | 2002 | 21A/11 | 4443 | 6500 | 2 | Angler logbook (caught 3) |
| Third Lake * | Digby | 1995 | | | | 2 | Angler logbook (caught 57) |
| Swallow Lake | Digby | 2000 | 21B/01 | 4411 | 6601 | 1 | Angler logbook (caught 1) |
| Clearwater Lake * | Digby | 2003 | | | | 1 | RFAC meeting |
| English Lake | Digby | 2003 | 21B/01 | 4410 | 6603 | 2 | Personal conversation |
| Barrett Lake | Halifax | 1988 | 11D/13 | 4449 | 6341 | 2 | Angler logbook (caught 33) |
| Bayer Lake | Halifax | 1994 | 11D/14 | 4448 | 6309 | 2 | Angler logbook (caught 5) |
| Long Lake | Halifax | 1994 | 11D/12 | 4437 | 6338 | 2 | Angler |
| Scraggy Lake | Halifax | 1994 | 11D/15 | 4458 | 6253 | 1 | RFAC |
| Big Indian Lake | Halifax | 1995 | 11D/12 | 4436 | 6343 | 1 | Angler logbook (caught 7) |
| Bissett Lake | Halifax | 1995 | 11D/11 | 4439 | 6328 | 2 | Angler |
| Fourth Lake * | Halifax | 1995 | | | | 1 | Angler logbook (caught 13) |
| Govenor Lake | Halifax | 1995 | 11E/02 | 4513 | 6240 | 2 | Angler |
| Wilson Lake | Halifax | 1995 | 11D/13 | 4449 | 6342 | 2 | Angler |
| Lake Echo | Halifax | 1996 | 11D/11 | 4443 | 6324 | 1 | Angler logbook (caught 29) |
| Papermill Lake | Halifax | 1997 | 11D/12 | 4443 | 6341 | 2 | Angler logbook (caught 10) |
| Pot Lake | Halifax | 1997 | 11D/14 | 4454 | 6310 | 1 | Angler logbook (caught 1) |
| DeSaid Lake | Halifax | 2000 | 11D/11 | 4438 | 6329 | 1 | Angler logbook (caught 5) |
| Brown Lake * | Halifax | 2004 | | | | 1 | Angler |
| Ragged Lake * | Halifax | 2004 | | | | 1 | Angler |
| Red Bridge Pond | Halifax | 2004 | 11D/12 | 4441 | 6333 | 1 | Angler |

*Table 3 (continued).*

| Water Body | County | Year | Topo Map | Latitude (Deg Min) | Longitude (Deg Min) | Confidence | Source |
|---|---|---|---|---|---|---|---|
| Dollar Lake * | Halifax | | 11D/14 | 4455 | 6319 | 1 | Angler |
| Shields Lake | Hants | 1982 | 11E/04 | 4510 | 6348 | 2 | Angler |
| White Rock Pond | Kings | 1972 | 21H/01 | 4503 | 6424 | 2 | Angler |
| Silver Lake | Kings | 1992 | 21H/02 | 4507 | 6436 | 2 | Angler |
| Black Duck Lake | Kings | 1995 | 21A/10 | 4443 | 6443 | 1 | Angler |
| Crooked Lake | Kings | 1996 | 21A/15 | 4454 | 6433 | 1 | Angler |
| Baptist Lake * | Kings | | 21A/16 | 4452 | 6426 | 2 | Unknown |
| Lilydale (Cantelope) Lake | Lunenburg | 1994 | 21A/08 | 4424 | 6421 | 2 | Angler logbook (caught 9) |
| Grimms Brook | Lunenburg | 1995 | 21A/08 | 4420 | 6420 | 2 | Angler logbook (caught 57) |
| Rhodes Lake | Lunenburg | 1995 | 21A/08 | 4422 | 6424 | 1 | Angler logbook (caught 2) |
| Little Beaver Lake | Lunenburg | 1997 | 21A/14 | 4416 | 6433 | 1 | Angler |
| Card Lake | Lunenburg | 2002 | 21A/09 | 4445 | 6417 | 1 | Angler |
| Island Lake | Lunenburg | 2004 | 21A/02 | 4415 | 6435 | 1 | Angler |
| Centre Lake * | Lunenburg | | | | | 1 | Angler |
| Lake Rossignol | Queens | 1995 | 21A/03 | 4410 | 6507 | 1 | Angler |
| Unnamed Caledonia Lake | Queens | 1999 | 21A/06 | 4421 | 6502 | 0 | Unknown |
| Beech Lake | Queens | 2002 | 21A/06 | 4427 | 6503 | 0 | Unknown |
| Bar Pond | Queens | 2003 | 21A/02 | 4410 | 6443 | 1 | Angler |
| Cannon Lake | Queens | 2008 | 21A/06 | 4521 | 6509 | 1 | Angler |
| Turtle Lake | Queens | 2008 | 21A/06 | 4422 | 6508 | 1 | Angler |
| Alvins Lake | Shelburne | 2002 | 20P/11 | 4343 | 6524 | 1 | Angler |
| Halfmoon Lake | Yarmouth | 1994 | 21A/04 | 4402 | 6555 | 1 | Angler logbook (caught 5) |
| Spar Lake | Yarmouth | 1994 | 20P/13 | 4353 | 6540 | 1 | Angler |
| Allen Lake | Yarmouth | 1997 | 20O/16 | 4357 | 6609 | 1 | Angler |
| Darlings Lake | Yarmouth | 1997 | 20O/16 | 4358 | 6608 | 1 | Angler |
| Sunday Lake * | Yarmouth | 1998 | | | | 1 | Angler |
| Beaverhouse Lake | Yarmouth | 2002 | 21A/04 | 4403 | 6548 | 1 | Angler logbook (caught 13) |
| Great Pubnico Lake | Yarmouth | 2002 | 20P/12 | 4342 | 6543 | 1 | Angler |

*Table 4. Two-sample t-test for lake morphological parameters thought to influence occurrence of smallmouth bass in Nova Scotia.*

| Lake | Bass Present | | | Bass Absent | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | N | Mean | Variance | N | Mean | Variance | t-stat | P | z-score | Significant |
| Surface Area | 100 | 215.3 | n/a | 907 | 65.59 | n/a | -6.05 | 0.00000 | 2.37 | Yes |
| Mean Depth | 87 | 3.42 | 4.21 | 814 | 2.67 | 3.87 | -3.35 | 0.00083 | 3.24 | Yes |
| Maximum Depth | 100 | 10.65 | 38.86 | 907 | 7.94 | 44.64 | -3.87 | 0.00012 | 4.09 | Yes |
| Shoreline Development Index | 100 | 2.17 | 0.85 | 894 | 1.85 | 0.66 | -3.76 | 0.00018 | 3.38 | Yes |
| Secchi Disk | 81 | 2.73 | 1.63 | 681 | 2.91 | 8.03 | 0.58 | 0.56248 | 1.03 | No |

*Table 5. Smallmouth bass and speckled trout angling catch per unit effort (CPUE), 2003-2008.*

| Year | Effort (hours) | Number of trout | CPUE (trout / hr) | Number of bass | CPUE (bass / hr) |
|---|---|---|---|---|---|
| 2003 | 10 | 15 | 1.50 | 3 | 0.30 |
| 2004 | 10 | 12 | 1.20 | 3 | 0.30 |
| 2005 | 10 | 2 | 0.20 | 5 | 0.50 |
| 2006 | 48 | 41 | 0.85 | 14 | 0.29 |
| 2007 | 15 | 9 | 0.60 | 6 | 0.40 |
| 2008 | 85.5 | 10 | 0.12 | 140 | 1.64 |

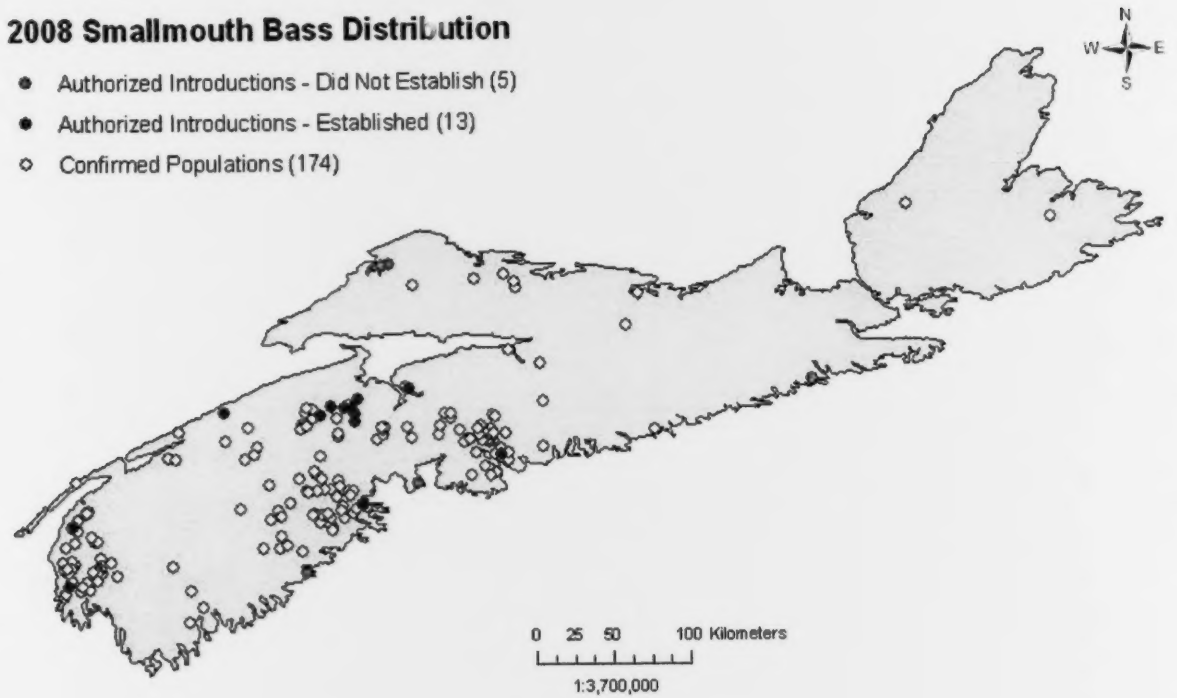


*Figure 1. Known distribution of smallmouth bass in Nova Scotia showing locations of authorized introductions that did not establish populations (blue), authorized introductions that successfully established populations (red) and established populations resulting from natural dispersals or illegal transfers (white).*

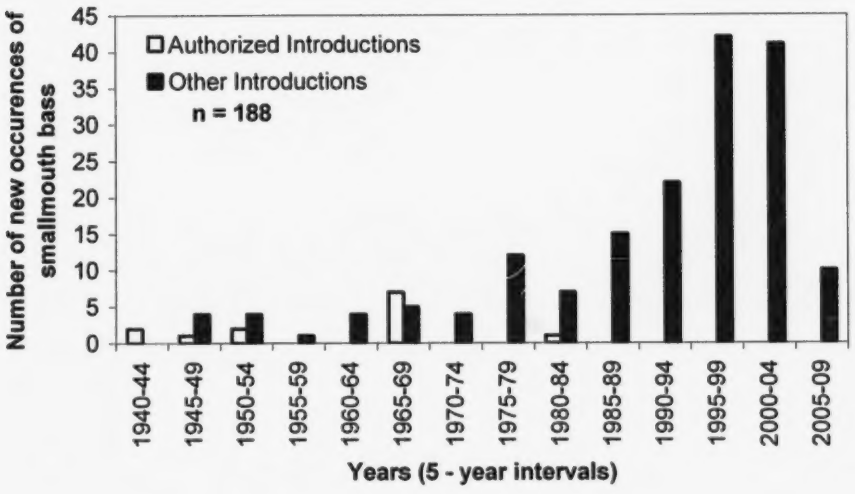


*Figure 2. Increase in new occurrences of smallmouth bass from 1942-2009. The 2005-09 interval is under-represented and does include documented populations found after April 2009.*

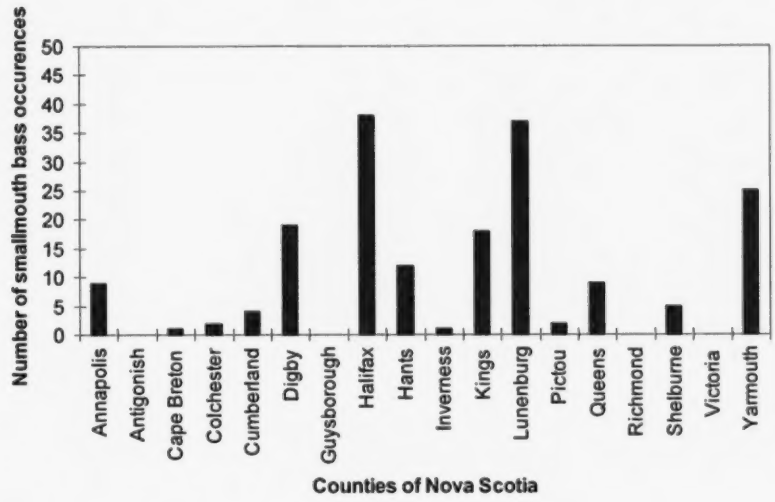


*Figure 3. Smallmouth bass occurrences by County in Nova Scotia, April 2009.*

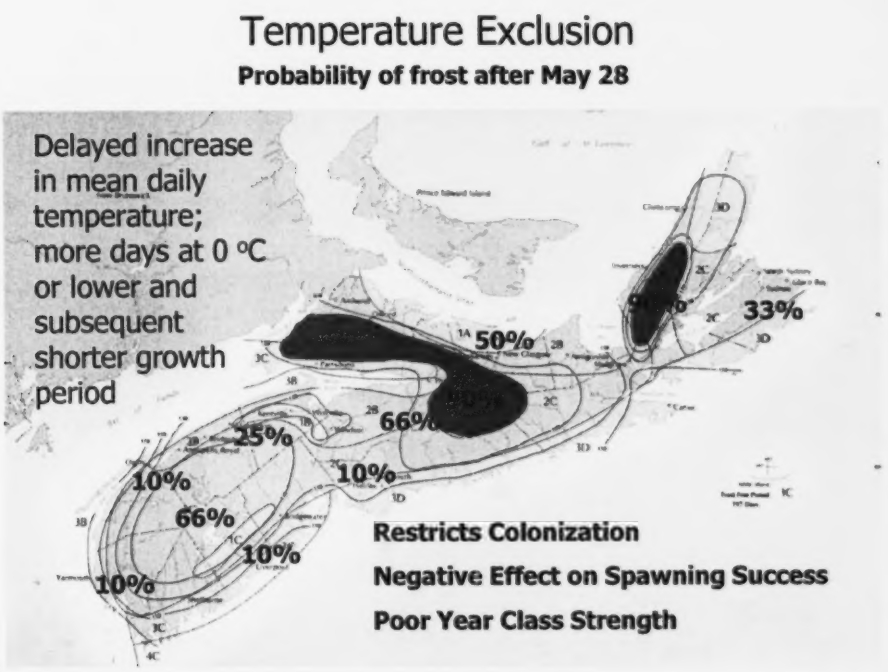


*Figure 4. Smallmouth bass temperature exclusion zones in Nova Scotia showing the probability of frost occurring after May 28.*

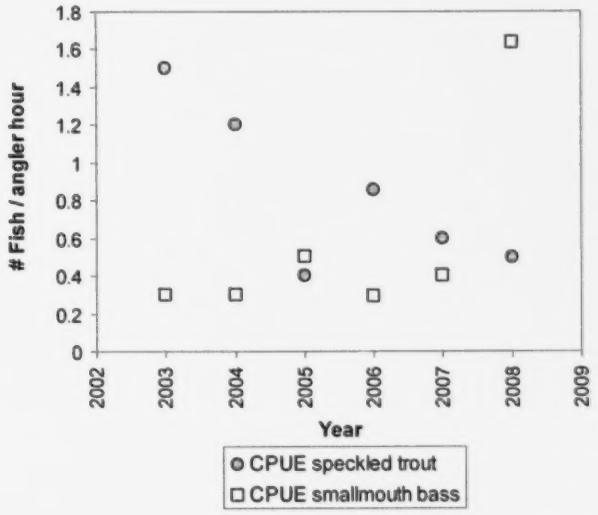


*Figure 5. Catch per angler hour for speckled trout ($r^2$ = 0.61) and smallmouth bass ($r^2$ = 0.47) in Lake Ainslie from Inland Fisheries angling surveys during May through July, 2003-2008.*

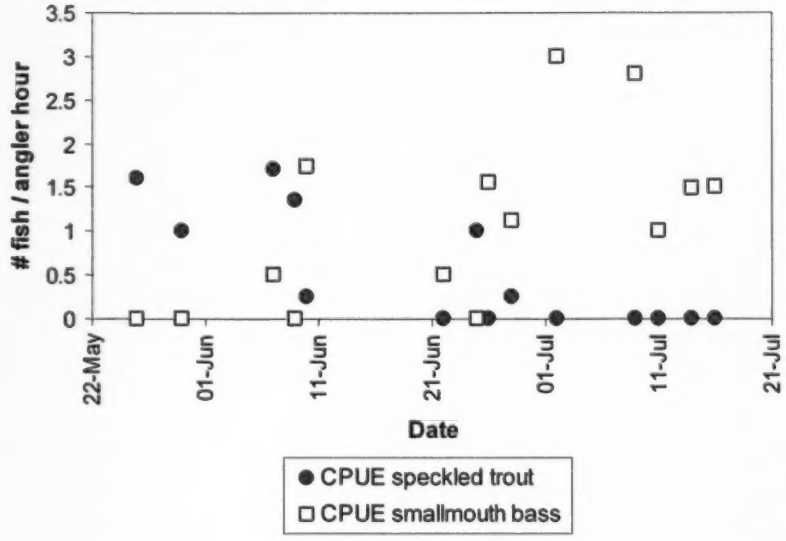


*Figure 6. Seasonal variation in catch per angler hour for speckled trout ($r^2$ = 0.38) and smallmouth bass ($r^2$ = 0.63) in Lake Ainslie from Inland Fisheries angling surveys during May through July, 2008.*

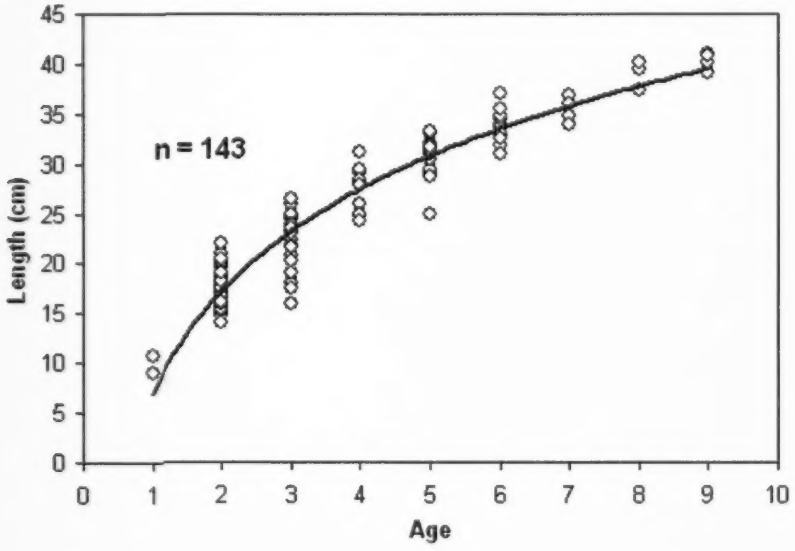


*Figure 7. Length at age for smallmouth bass from Lake Ainslie (2008) from angling and gill netting surveys (n=143).*

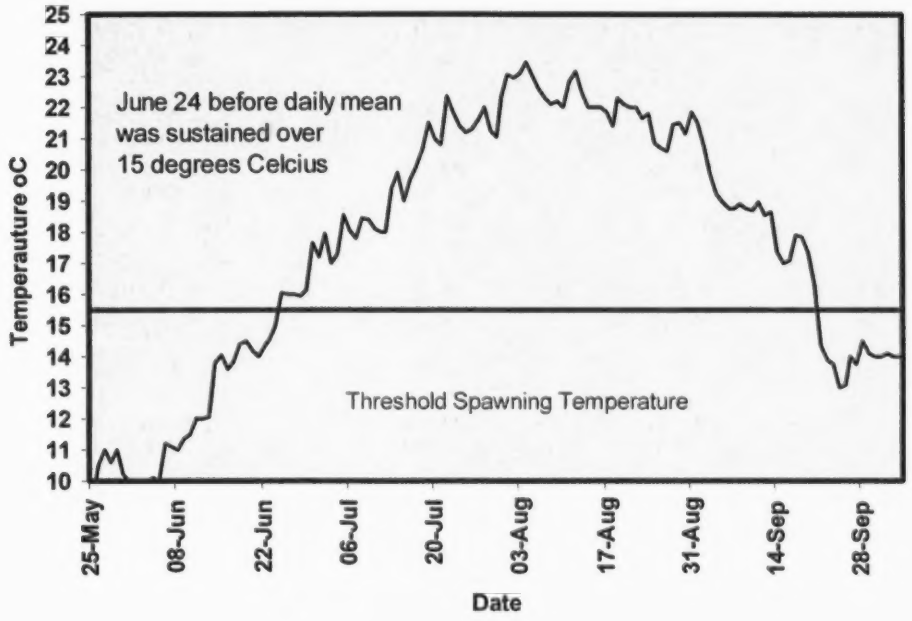


*Figure 8. Mean daily water temperature in Lake Ainslie (2004) showing late June start of days with adequate spawning temperatures.*